Exploring the Aesthetic Effects of the Golden Ratio in the Design of Interactive Products

Completed Research Paper

Noam Tractinsky
Ben-Gurion University of the Negev
noamt@bgu.ac.il

Efrat David
Ben-Gurion University of the Negev
efratda1@gmail.com

Arseny Krupnik
Ben-Gurion University of the Negev
arsenikr@gmail.com

ABSTRACT

We conducted an experiment to test whether the use of the golden ratio as a design guideline in interactive products has aesthetic value, that is, whether it influences users' aesthetic evaluation of the product and their preferences for it over other product of the same type. We studied two types of products (mobile phones and web pages), each was wireframed in two design versions and then manipulated systematically to form various width × height proportions, including the golden ratio. Each of ninety-one participants evaluated one design version of each product by means of pairwise comparisons of all proportions. The results support the golden ratio hypothesis regarding the mobile devices but not regarding the web page designs. We discuss possible explanations for these results.

Keywords

Golden ratio, interactive products, design, aesthetic preferences.

INTRODUCTION

The recognition that the visual aesthetics of interactive systems and products serves an important role in enhancing users' experience and satisfaction (Tractinsky, 2004) has motivated designers and researchers in the field of human-computer interaction (HCI) to decipher the code that leads to attractive interactive products (Tractinsky, 2006). The attempts to understand what makes products attractive and how to design for visual appeal have led researchers through different paths. For example, some studies focused on users perceptions of product aesthetics (e.g., Lavie and Tractinsky, 2004; Park et al., 2004; Moshagen and Thielsch 2010; Cyr et al, 2010). Other studies focused on identifying structural aspects of the design, such as symmetry and balance, that improve aesthetic perceptions (e.g., Ngo et al., 2003; Bauerly and Liu, 2006, 2008; Schmidt et al., 2009). Of course, numerous design guidelines and rules of thumbs were proposed by designers, mostly without any empirical evaluation of their validity.

Recently, suggestions, accompanied by various examples, were made in design circles that the golden ratio -- a well-known mathematical proportion, also presumed to be favored by generations of artists and designers – can contribute to the aesthetics of interactive products. We term this claim the golden ratio hypothesis. The claim is in line with the structuralist approach mentioned above. Moreover, if substantiated, the golden ratio hypothesis can provide a relatively parsimonious aesthetic guideline for designers and developers of interactive products' interfaces. However, the anecdotal evidence regarding the applicability of the golden ratio as design principles should be taken with a grain of salt for two main reasons. First, the golden ratio can be fitted retrospectively to designed objects or can be applied arbitrarily to certain elements of the design but not to others. Thus, ad hoc findings of the golden ratio in favorite designs and works of arts is considered "data fishing" rather than evidence achieved by adequate scientific procedure. Second, we are not aware of any scientific examination of the alleged contribution of the golden ratio to users' aesthetic perceptions of interactive products. Thus, the objective of this research is to provide a more systematic evaluation of the golden ratio hypothesis in the domain of interactive products.

BACKGROUND

The term Golden Ratio (also known as Golden Section and denoted φ) was coined in the first half of the 19th century, although the geometrical proportion expressed by this ratio (about 1.618) has occupied generations of mathematicians,

scientists and artists, since defined by Euclid around 300 BC (Livio, 2002). The Euclidian definition refers to the case of a line, which when divided into two segments creates a golden ratio if the proportion of the whole line to the longer segment is equal to the proportion of the longer segment to the shorter segment (see Figure 1). The golden ratio can also be found in various ways in more complicated geometric shapes such as polygons and spirals, and of course in various mathematical and natural domains.

$$\frac{a}{b} = \frac{a - b}{a}$$

Figure 1: A line divided by the golden ratio.

Empirical investigation of the effects of the golden ratio on perception and aesthetic preferences are among the earliest in the field of psychology (Green, 1995, Benjafield, 2010). The earliest experiments were conducted by Fechner within the framework of psychophysics during the 1860s, under the title of "experimental aesthetics" with the aim of discovering those aspects of art objects that made them pleasing to spectators (Benjafield, 2010). Fechner's motivation to study the golden section was probably motivated by strong claims of contemporary philosopher, Adolf Zeising, who argued that the golden section can be found anywhere in nature and considered it a law of proportion that was as important as the laws of logic (Benjafield, 2010). This perspective is considered the "strong version" of the golden ratio hypothesis. Fechner's procedures and findings were often misrepresented by subsequent generations of researchers (Green, 1995). According to Green, 35% of the responses in Fechner's experiment preferred the golden ratio out of 10 possible ratios of rectangles, and 40% more expressed preference for ratios adjacent to the golden ratio. Still, none of the responses selected the golden ratio as the least preferred proportion. Thus, while not supporting the strong version of the hypothesis, Fechner's studies supported a weaker version of it. That is, the most pleasing proportion may not necessarily conform to the exact golden ratio, but to a range of pleasing proportions that hovers around the golden ratio.

Dozens of subsequent studies yielded many conflicting results, ranging from a complete rejection of the golden ratio hypothesis (e.g., Bosseli, 1992) to support of its weaker version, to (infrequently) support of its stronger version (cf. Green, 1995; Benjafield, 2010). Proponents of the unique qualities of the golden ratio suggested various explanations for why people would prefer it over other proportions. For example, Arnheim (1954, in Green, 1995) argues that the golden ratio balances best the two desired, yet conflicting aesthetic criteria of unity and variety. Others suggested that the golden ratio approximates the dimensions of the human visual field, a claim supported by the findings of many studies that people prefer horizontal orientation over vertical orientation of rectangular shapes (namely, the "perimetric hypothesis"). An even stronger claim is made by Bejan (2009) who argues that the golden ratio represents the best proportions to transfer images to the brain: "…humans scan the world on a two-dimensional screen approximated by a rectangle with the shape L/H ~ 3/2. We scan the long dimension faster than the vertical dimension, in such a way that to scan long and fast … takes the same time as to scan short and slow... This is the best flowing configuration for images from plane to brain, and it manifests itself frequently in human-made shapes that give the impression that they were 'designed' according to the golden ratio" (Bejan, 2009, p. 101). This explanation resembles the processing fluency hypothesis, according to which easy processing of visual stimuli elicit positive affective responses (Reber et al., 2004; Winkielman et al., 2006).

Golden Ratio in Interactive Products

The notion of the golden ratio as a formula to create pleasing compositions filtered from academia to practice during the early 20th century. It became popular especially in the advertising industry and had an effect on important designers and architects such as Le Corbusier (Arnheim, 1955; Benjafield, 2010). Recently, claims about the use of the golden ratio in the design of interactive products and its merits can be found over the internet regarding, for example, Apple's ipod (e.g., Seidenberg , 2006) and Twitter's web site (e.g., http://www.flickr.com/photos/twitteroffice/5034817688/). Tutorials and recommendations regarding the use of the golden ratio in web design can be found as well (e.g., Remick, 2008). Interestingly, standard display sizes of current computer displays (both stand-alone and laptop displays) hover around the golden ratio (e.g., 8:5 or 16:9). Similarly, the proportions of popular smart phones' displays also resemble the golden ratio (e.g., first generations of iPhone had aspect ratio of 3:2, while iPhone 5's aspect ratio is 16:9).

To the best of our knowledge, no systematic research has been conducted thus far regarding the effects of using the golden ratio in designs of HCI artifacts. Thus, our objective is to explore whether such effects exist. For this purpose we conducted

an experiment in which we tested the effects of varying the proportion of two types of interactive products – web pages and mobile devices - on users' preferences.

METHOD

We conducted an experiment to examine whether designs that rely on the golden ratio are preferred to designs in other proportions, using two types of interactive products: Web pages and mobile devices. These types represent highly used interactive objects that are also quite different from each other (in terms, e.g., of size, hardware vs. software). The use of two different product types should inform us about the generalizability of the findings. Below we detail the experimental method.

Stimuli

For each product type (web page or mobile device) we designed two different wireframes as can be seen in Figure 2, to serve as baseline for stimuli generation in the experiment. The choice of wireframe design was made to prevent potential effects of content and of other potential confounding design factors (cf. Tractinsky, 2006).

Figure 2: Study baseline stimuli: Baseline designs of the two web pages and two mobile devices

From each baseline design we created several variants of different proportions, including the golden ratio (GR). The proportions were varied by a factor of about 10%, as follows.

Web pages: We created two version of each web design: one horizontal and one vertical. Each of those versions included a design with the GR proportion and additional designs in proportions that increased or decreased by a factor of 10%. Thus, for the first design baseline the vertical version (see sample stimuli in Figure 3) included a height-to-width proportion of the GR (1.62), two designs with proportion lower than the GR (1.31 and 1.46) and two designs with proportions greater than the GR (1.78 and 1.96). Similarly, the horizontal version included the golden ratio surrounded by four additional proportions (0.48, 0.54, 1/GR (0.62), 0.68, and 0.76). Thus, there were 10 versions for each of the two web page baseline designs.
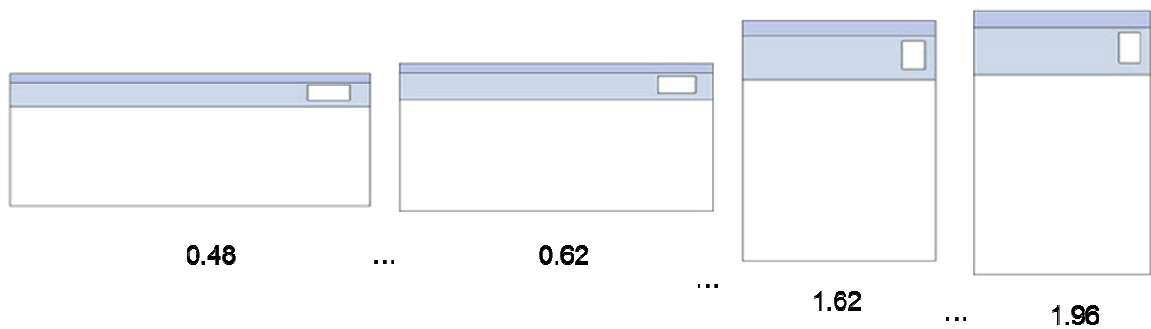
Figure 3: Four out of ten versions of one of the web page designs in horizontal (left) and vertical positions. Numbers indicate the proportion of the page's height to its width.

Mobile devices: The mobile devices were presented only vertically, to reflect the realistic way in which smart phones are usually being presented and held. We manipulated only the devices' screens to preserve the overall familiar shape and proportion of mobile devices, which usually have a height-to-width ratio close to 2:1. We created seven variants of each baseline design. The variants included the GR, three designs with proportions lower than the GR and three designs with proportions greater than the GR (i.e., proportions of 1.17, 1.31, 1.46, 1.62, 1.78, 1.96, and 2.15). Figure 4 depicts a sample of the design variants of one baseline cell phone design.

Figure 4: Three out of seven versions of the second mobile device. Numbers indicate the proportion of the device's *screen* height to its width.

Sample

Ninety-one Information Systems Engineering students (average age = 25, SD = 2.9; 33 females) volunteered to participate in the study for class credit.

Experimental Design

A 2×2 between-groups design was used in which each condition included the evaluation of a set of the various proportions of one baseline web page design and a set of the various proportions of one baseline mobile device design (see Table 1). Thus, each baseline design was evaluated by two groups: Forty six participants evaluated Mobile Device 1; 45 evaluated Mobile Device 2; 43 evaluated Web Page 1; and 48 evaluated Web Page 2. Participants were assigned randomly to experimental groups.

	Web Page 1	*Web Page 2*
Mobile Device 1	N = 21	N = 25
Mobile Device 2	N = 22	N = 23

Table 1. Experimental design and number of participants in each group.

Procedure

The procedure for eliciting aesthetic preference was designed to overcome a potential bias in early studies in which all stimuli were presented at once (Green, 1995). In such a procedure, participants might be biased towards the GR if it lay at the center of the range of objects to be evaluated, as is the case in most GR studies and in particular in the current study. Thus, we measured aesthetic preferences using a procedure of pair-comparisons of all possible pairs of stimuli. The participants viewed each pair at a time and responded to the question "Which design of a mobile device (web page) do you perceive as more beautiful?" by selecting, on an 11-point scale, the button that reflects their answer (see Figure 5). The response scale was not numbered to prevent any bias due to the order of the numbers. Instead, only two anchor points were provided at the extremes of the scale: Left Phone (Web Page) and Right Phone (Web Page). Participants were instructed to select the left-most button if they absolutely preferred the left design, to select the middle button if they were indifferent between the designs, and so on.

Overall, participants in each group evaluated 21 pairs of mobile devices and 45 pairs of web pages. The order in which pairs of mobile devices and web pages were presented to the participants was randomized for each participant.
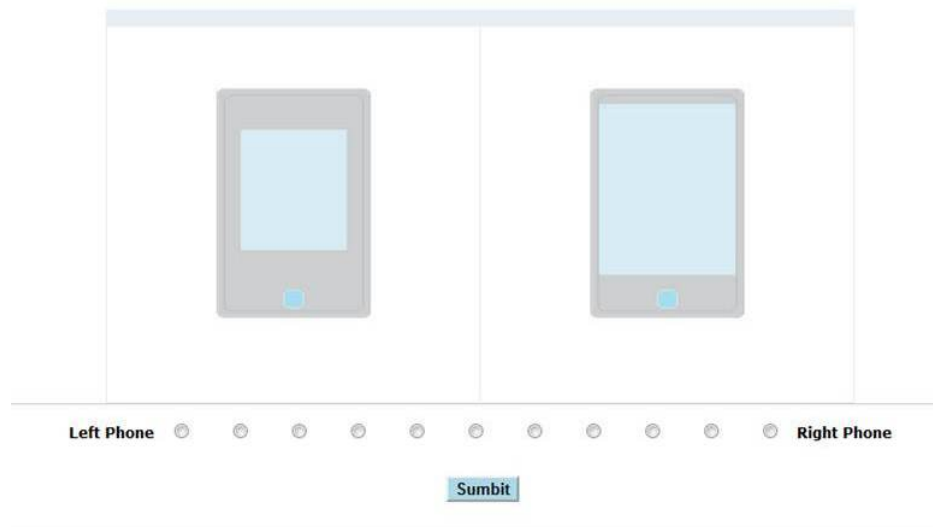
Figure 5: A screen shot of the preference elicitation procedure.

RESULTS

Participants' responses to each pairwise comparison were coded as preference of each of the stimuli as follows: selecting an extreme radio button was scored as complete preference for the design at this end (a score of 1.0) and as a complete lack of preference for the other design (a score of 0.0). Selecting an interim button was scored proportionally between the two designs (e.g., if the next to most extreme button was selected, scores of 0.9 and 0.1 were given to the adjacent and to the remote designs, respectably; if the middle button was selected, scores of 0.5 were given for both designs). We continue with the analysis of the mobile devices first and then with the results of the web pages.

Mobile Devices

For each mobile device design, preference scores were averaged for each proportion over all participants. For each proportion, we conducted an independent sample t-test for the difference between preference scores of the two baseline designs. All seven t-tests were insignificant, indicating a lack of interaction between the baseline design and screen proportion. Consequently, we pooled the data from the two designs before continuing to analyze the data for differences between screen proportions.

Of the seven proportions of the mobile devices' screen, the participants preferred the golden ratio the most (M=0.76, SD=0.19), with the 1.78 ratio a close second (M=0.75, SD=0.11). The average preferences of all the proportions are presented in Figure 6. In addition, Figure 7 concentrates on head-to-head comparisons between the golden ratio and the other proportions.

A one way repeated measures ANOVA yielded a significant effect of design proportion on aesthetic preference scores ($F_{(6, 540)}$= 133.969, $p<.001$, partial η^2 = .60). Post hoc comparisons with Bonferroni adjustments revealed that the golden ratio was significantly preferred over five of the other six proportions. Preference for the GR was not significantly different only from preference for the 1.78 ratio, which in turn was also significantly preferred over the other five ratios.
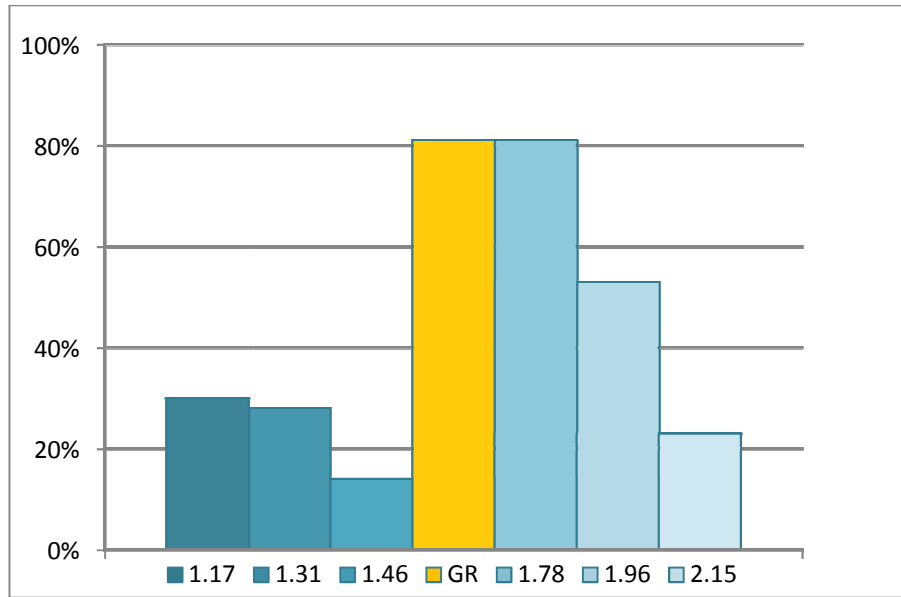
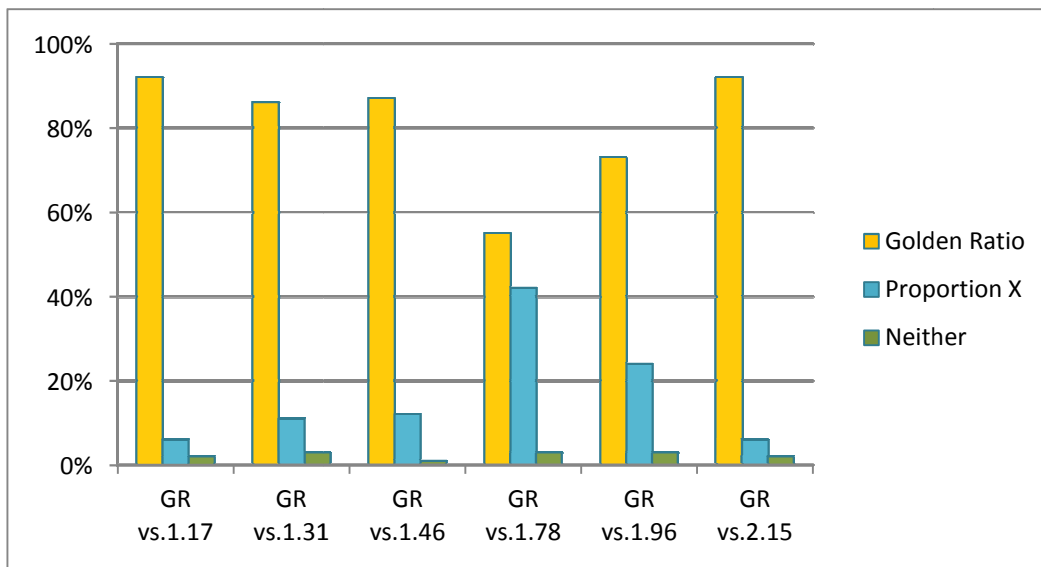**Figure 6: Average preference of screen ratios of mobile devices.**

Figure 7: Average preference score of the golden ratio designs in head-to-head comparisons against the other proportions.

Web Pages

Preference scores of the web pages were averaged for each proportion over all participants. The average preferences are presented in Figure 8. For each proportion, we conducted independent sample t-tests for differences between the two web page designs in each proportion. Of the ten proportions we found significant differences between two of the horizontal layout designs. These differences involved the 0.54 proportion (p<.001) and the 0.76 proportion (p<.01). The web page with the wide vertical bar) was preferred more in the wider and shorter 0.54 proportion (M=0.39, SD=0.12 vs. M=0.30, SD=0.12), whereas the other web page (with the wide horizontal bar) was preferred in the narrower and higher 0.76 proportion (M=0.78, SD=0.14 vs. M=0.68, SD=0.18).
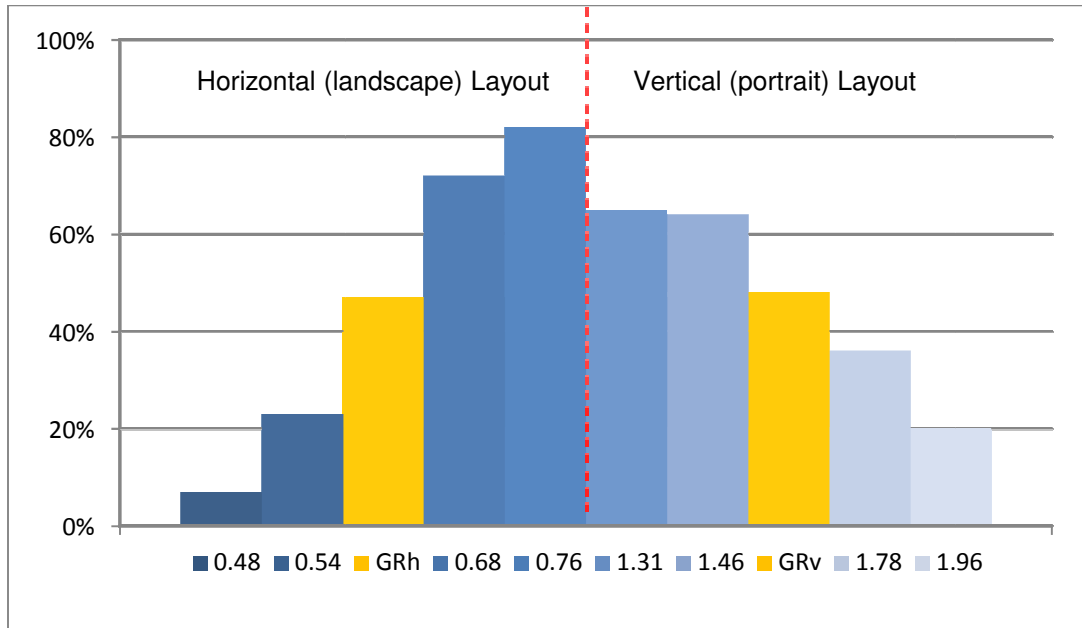
Figure 8: Average preference scores for ten web page proportions

Repeated measures ANOVA on the pooled data from both designs revealed a significant effect of design proportion on aesthetic preference scores ($F_{(9, 810)}= 84.296$, $p<.001$, partial $\eta^2 = .48$). Post hoc comparisons with Bonferroni adjustments revealed that proportions closer to 1.0 (i.e., 0.76 and 0.68 in the horizontal layout, and 1.31 and 1.46 in the vertical condition) were most preferred. The golden ratio designs were only preferred to the more extreme ratios (i.e., the more rectangular designs) but were less preferred compared to ratios closer to a square proportion. Figure 9 depicts the percentage of participants who preferred the web page design in the golden ratio, the other proportion, or neither one, in head-to-head comparisons.
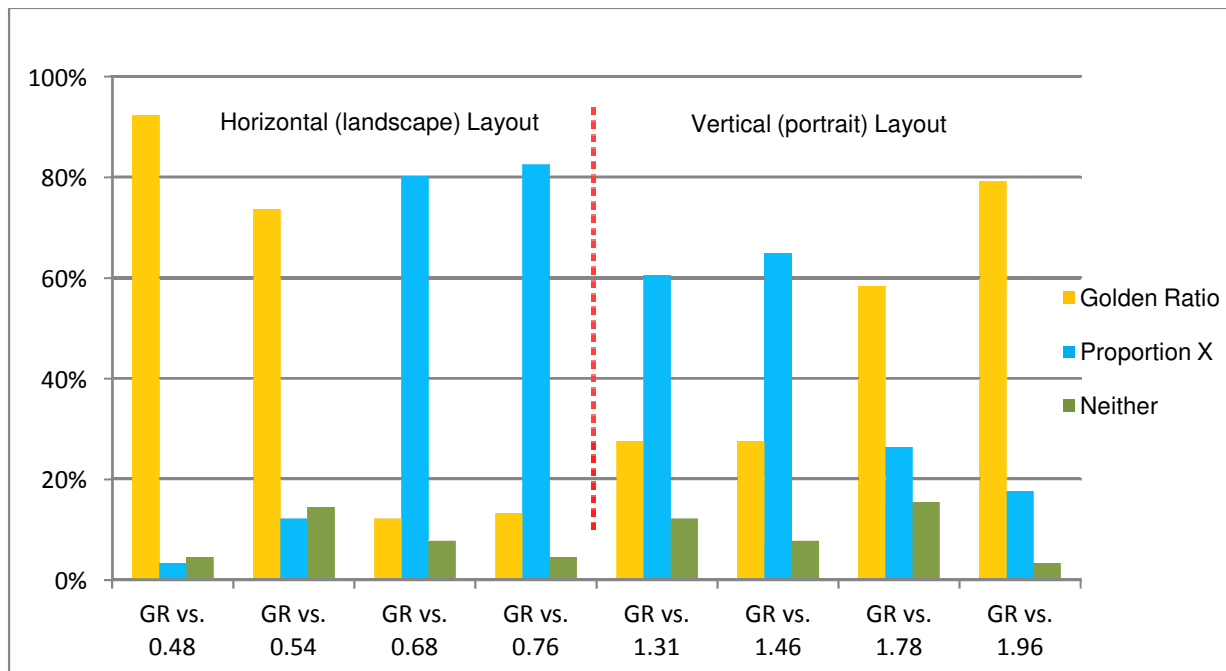

Figure 9: Average preference score of the golden ratio designs in head-to-head comparisons against the other proportions.

DISCUSSION

To the best of our knowledge this is the first study to examine the effects of the golden ratio on people's aesthetic preferences in the context of interactive products. To evaluate this research question, the study employed wireframe designs of two different types of products – web pages and mobile devices. The results of the mobile devices provide support for the golden ratio hypothesis, at least in its weak version. That is, with one exception devices with displays proportioned according to the golden ratio were preferred to device designs whose display proportions deviated from the GR. The only exception was a design with a display ratio of 1.78, which was as aesthetically preferred as the GR display. The preference for the 1.78 proportion is still commensurate with the weak GR hypothesis, as it was one of the two ratios adjacent to the GR. Still, it is interesting to note that the GR was significantly preferred to the 1.46 ratio - the other adjacent ratio. One possible explanation for this finding is the effects of familiarity (Reber et al., 2004, Winkielman et al., 2006) of users with mobile devices and with design trends (Korman-Golander et al., 2012) in the smart phone industry. Because mobile devices tend to have an overall shape that is longer than the golden ratio, and as the tendency over time has been to increase the display ratio due to increasing the vertical aspect of mobile device displays, people may be more inclined to prefer a proportion that is slightly longer than the GR (1.78 in our case) but not a proportion that is slightly wider (1.46) than it.

However, the results of the web page designs contradicted the golden ratio hypothesis. Here, the GR designs were just in the middle of the pack in terms of users' preferences. The participants preferred web pages in proportions closer to a square both in the horizontal (the 0.76 and 0.68 ratios in our study) and the vertical (the 1.31 and 1.46 ratios) comparisons. This finding is somewhat surprising given the prevalence of computer displays shaped in aspect ratios that are similar to the GR (16:10) or which are even more rectangular (16:9). In fact, our participants preferred design proportions that are more in line with aspect ratios of older generation displays such as 4:3. Interestingly, this finding stands in contrast to the recent move by the display industry to the more rectangular aspect ratio due to manufacturing costs and attempts to make them compatible with HD television displays (Vermulen, 2011) and gaming standards. However, since users can adjust the browser size to less than full-screen size, they may still have the discretion to decrease its width and thus to create a window in proportions that more resemble the preferences exhibited in our study.

Another interesting finding from the web page design domain relates to preference differences between the two different baseline designs in the proportions of 0.54 and 0.76. The preference of the web page with the vertical side bar in the wider and shorter 0.54 proportion and of the web page with the horizontal top bar in the narrower 0.76 proportion may have to do with the interaction of the overall page ratio, which was manipulated systematically, and its other design elements, which were not manipulated independently of the main manipulation. Thus, we cannot point at the exact nature of the interaction.

 These findings, taken together with the conflicting results regarding the effects of the GR in the domains of mobile devices and web pages, may indicate that the GR cannot be used as a design silver bullet, but nor should it be dismissed altogether as a design idea. Rather, a more contingent approach to its effects and interactions with other contextual and design elements should be adapted. For example, the reasons for the support for the GR hypothesis in the area of mobile devices may stem from the fact that it depicted a product whose proportions cannot be changed by the user, as opposed to web pages. Another difference between the two domains studied here is that the ratio in the web pages domain included the artifact's external frame, whereas the proportions in the mobile device domain included an internal part whereas the external frame remained constant.

It is likely that low-level design features such as GR are not in and of themselves sufficient to define the whole of the aesthetic evaluation. Thus, higher-level constructs that stem from the amalgamation of low-level features hold promise for stronger predictive value regarding aesthetic preferences than individual low level attributes. Nevertheless, it is possible that when the visual design is relatively simple (as in the shape of mobile devices, as opposed to most web pages) such stand-alone low level attributes may play a greater role in influencing aesthetic evaluations and preferences.

Due to its exploratory nature, this study has several limitations that should be addressed in future studies. The limitations include the relatively simplistic wireframe representation of the interactive products and the manipulation of only one aspect of the design of each product (the web page's frame and the mobile device's display). Another limitation relates to the nature of the sample, which was composed of technologically savvy young people, who are highly familiar with mobile devices and who are used to customize the shape of their web browser while working on larger displays (i.e., on desktops and notebooks). These limitations represent the inevitable tradeoff between the current study's emphasis on internal validity and the worldly realism which could not have been addressed here, but which should be part of a future research program on this topic.

CONCLUSION

Early experimental research on the GR employed simple, and often stimuli that were out of context or, in the tradition of aesthetic research, lacked any pragmatic aspect. In this study we framed the experimental task in the domain of popular interactive products. The results of the study are mixed, supporting the GR hypothesis in one product domain but not in the other. Failing to unequivocally reject or support the GR hypothesis, the evidence suggests that more research is needed to evaluate the merits of the GR in interactive product design. The lack of conclusive evidence indicates that in our quest for principles of aesthetic design we should look more into the contingencies that enable the GR to improve the aesthetic experience and for those that either magnify or diminish its effects.

REFERENCES

1.   Arnheim, R. (1955) A review of proportion: *The Journal of Aesthetics and Art Criticism*, 14(1), pp. 44-57.

2.   Bauerly, M. and Liu, Y. (2006) Computational modeling and experimental investigation of effects of compositional elements on interface and design aesthetics, *International Journal of Human-Computer Studies*, 64, 670–682.

3.   Bauerly, M. and Liu, Y. (2008) Effects of Symmetry and Number of Compositional Elements on Interface and Design Aesthetics, *International Journal of Human-Computer Interaction*, 24(3), 275–287.

4.   Benjafield, J.G. (2010) The golden section and American psychology, 1892-1938, *Journal of the History of the Behavioral Sciences*, 46, 1, 52–71.

5.   Bejan, A. (2009) The golden ratio predicted: Vision, cognition and locomotion as a single design in nature, *International Journal of Design & Nature and Ecodynamics*, 4(2), 97-104.

6.   Boselie, F. (1992) The golden section has no special aesthetic attractivity!, *Empirical Studies of the Arts*, 10, 1-18.

7.   Cyr, D., Head, M. and Larios, H. (2010) Colour appeal in website design within and across cultures: A multi-method evaluation, *International Journal of Human-Computer Studies*, 68, 1-21.

8.   Green, C.D. (1995) All That Glitters: A review of psychological research on the aesthetics of the golden section, *Perception*, 24, 937-968.

9.   Korman-Golander, G., Tractinsky, N., and Kabessa Cohen, I. (2012) Trends in website design, *AIS Transactions on HCI*, 4, 3, pp. 169-189.

10. Lavie, T. and Tractinsky, N. (2004) Assessing dimensions of perceived visual aesthetics of web sites, *International Journal of Human-Computer Studies*, 60, 3, 269-298.

11. McManus, I.C. and Weatherby, P. (1997) The golden section and the aesthetics of form and composition: A cognitive model, *Empirical Studies of the Arts*, 15, 2, 209-232.

12. Moshagen, M. and Thielsch, M.T. (2010) Facets of visual aesthetics, *International Journal of Human-Computer Studies*, 68,689–709.

13. Ngo, D.C.L., Teo, L.S., and Byrne, J.G. (2003) Modelling interface aesthetics, *Information Sciences* 152, 25–46.

14. Park, S., Choi, D., Kim, J. (2004) Critical factors for the aesthetic fidelity of web pages: empirical studies with professional web designers and users, *Interacting with Computers*, 16, 351–376.

15. Reber, R., Schwarz, N., and Winkielman, P. (2004) Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review*, 8, 4, 364–382.

16. Remick, J. (2008) The Golden Ratio in Web Design. Available online: http://net.tutsplus.com/tutorials/other/the-golden-ratio-in-web-design/ (last accessed February 17, 2013).

17. Schmidt, K.E., Liu, Y., and Sridharan, S. (2009) Webpage aesthetics, performance and usability: Design variables and their effects, *Ergonomics*, 52, 6, 631–643.

18. Seidenberg, J. (2006) Golden ratio in the design of the iPod. Available online: http://deltaflow.com/home/blog-archive/golden-ratio-in-the-design-of-the-ipod/ (last accessed February 17, 2013).

19. Tractinsky, N. (2004) Towards the Study of Aesthetics in Information Technology, *Proceedings of the 25th Annual International Conference on Information Systems (ICIS)*, Washington, DC, December 12-15, pp.771-780.

20. Tractinsky, N. (2006) Aesthetics in information technology: Motivation and future research directions, in Zhang, P. and Galletta, D. (Eds.) *Human-Computer Interaction in Management Information Systems: Foundations*, M. E. Sharpe, Inc, 330-347.

21. Vermulen, J. (2011) Widescreen monitors: Where did 1920×1200 go? Available online: http://mybroadband.co.za/news/hardware/17621-widescreen-monitors-where-did-1920x1200-go.html (last accessed February 17, 2013).

22. Winkielman, P., Halberstadt, J., Fazendeiro, T., Catty, S. (2006) Prototypes are attractive because they are easy on the mind, *Psychological Science*, 17, 9, 799-806.